1999 SWAT MONITORING PROGRAM REPORT

PART 4 SPECIAL STUDIES

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4.1

KINGFISHER AS A UNIVERSAL INDICATOR

KINGFISHERS AS A UNIVERSAL INDICATOR OF EXOSURE ASSESSING METHYLMERCURY AVAILABILITY IN MAINE'S AQUATIC SYSTEMS WITH THE BELTED KINGFISHER, 1998-99.

David Evers and Oxana Lane, BioDiversity Research Institute

Mercury and other aquatic-based persistent bioaccumulative toxic contaminants are prevalent in Maine's freshwater and marine environments. Making comparisons between various ecosystems over a large geographic range requires the use of a standardized method. Species accumulate contaminants differently and, to date, the state of Maine has not identified either a single species or method that enables a fair comparison of all environments.

1. Kingfisher natural history: The Belted Kingfisher (*Ceryle alcyon*) is a relatively common and widely distributed obligate piscivore. It inhabits a diversity of breeding habitats ranging from small streams to large rivers, ponds to large lakes and reservoirs, emergent wetlands, estuaries, and marine environs. It feeds on small prey items that are generally 14 cm or less. Adult male kingfishers may be permanent residents on territories with yearround water access (e.g., rivers and estuaries). In ice-locked territories, females generally return first after migration. Maine nesting pairs inhabit their breeding territory from mid April into early August. Nesting and foraging territories are strongly defended by both sexes against conspecifics (Davis 1982). Territory size depends on nest and food availability and juxtaposition of feeding areas. Nest burrows are in open banks and can be accessed for repeated sampling of the young. Both sexes share the 24 day incubation of 5-7 eggs. Nesting typically begins in early to mid May. Hatching occurs by early to mid June and within another 4 weeks young leave the nest burrow. The average brood of 4 fledglings typically remain within 300-500 m of the nest burrow for the next 3-4 weeks, frequently being fed by their parents (D. Albano, pers. comm.).

2. Mercury exposure to kingfishers: The diet of fish and crayfish puts the Belted Kingfisher at-risk from persistent bioaccumulative toxins such as mercury. The co-authors have collected small cyprinnids (5-15 cm) from 4 reservoirs and 4 natural lakes in northwestern Maine. Their mean Hg levels were 0.3 ppm and some individuals contained over 1 ppm (i.e., Flagstaff Lake) (Evers and Reaman 1998). Blood Hg levels measured for kingfishers on Flagstaff and Chesuncook reservoirs (2.12 ppm) were 60% higher than those found on Maine natural lakes (1.26 ppm) (BioDiversity Research Institute unpubl. data).

The USEPA estimates a high intake of methylmercury (MeHg) for kingfishers (40 ug of MeHg per kg of body weight per day) - nearly 3x higher than the Osprey (*Pandion haliaetus*) and the Bald Eagle (*Haliaeetus leucocephalus*) (USEPA 1997). These estimates are based on average fish Hg levels of 0.08 ppm and a daily uptake of 75 g of fish. Mean Maine fish Hg levels are generally well above this and D. Albano (pers. com.) estimates that daily food uptake may be as much as 75-150 g of fish. Therefore, kingfishers are suitable indicators of MeHg availability and potentially other bioaccumulative contaminants.

Results: We captured Belted Kingfishers and their prey at 4 major habitat types: marine, estuary, riverine, and upper watershed lakes (separated into natural and impoundments). From May to July, 1998-99 we sampled from 46 nests and captured and collected blood samples from 38 adult and 106 juvenile kingfishers (Table 1). A total of 32 prey fish were collected at the burrow during capture of a parent. These prey items provided insight into species and size of prey for later prey capture in the kingfisher's territory.

Table 1. Sampling efforts for kingfishers, 1998-99.

Habitat Type	***No. nests sampled***		***No. Belted Kingfisher***[4] ***Adult***[1]		***Juvenile***[2]		***No. Prey Items nest***		***territory***	
	98	99	98	99	98	99	98	99	98	99
Marine (Casco Bay)	2	2	2	2	6	2	1	1	20	0[3]
Estuary (Mmtg Bay)	6	2	8	1	27	8	12	1	123	0[3]
Riverine (Andro/Ken)	3	13	3	9	2	20	0	12	0	31
Natural Lakes	1	3		2	7	1	0	3	0	22
Reservoirs (Flag/Azis.)	8	6	8	3	23	10	0	2	6[3]	0
Total	**20**	**26**	**21**	**17**	**65**	**41**	**13**	**19**	**143**	**55**

[1]Represents the number of adults for which blood and feather samples were collected.
[2]Represents the number of blood samples collected from juveniles, several of these sampled are pooled within a brood
[3]Prey were collected in kingfisher territories in past years for a loon-Hg study by BioDiversity Research Institute
[4]A total of 9 kingfisher eggs were also collected.

The mean adult and juvenile blood mercury for reservoir and riverine sample sites (both from a known high mercury site in the Flagstaff Lake area) tended to be higher than marine and estuarine sites. Mean juvenile blood mercury levels in upper watershed lakes were six times higher than coastal areas (Table 2). Juvenile blood mercury levels averaged seven times lower than adults and most likely reflect differences in prey size. Generally larger, older prey have more mercury than smaller, less piscivorous prey. Blood Hg risk thresholds are unknown for kingfishers. Feathers were sampled only from adults because juvenile feathers were still in sheath. Unlike blood, feather mercury levels show chronic body burden and probably provide some insight into individual age. The mean feather mercury level was 10 ppm with three individuals nearing known thresholds of high risk (i.e., >20 ppm) (USEPA 1997).

Table 2. Mean (+/- sd) mercury levels (ppm) in kingfisher matrices, 1998.

Habitat Type	Ad-blood	Ad-feather	Juv-blood	A/J Ratio*
Marine (Casco Bay)	0.24 +/- 0.16	10.0+/-0.85	0.04 +/- 0.01	6.0
Estuarine (Merrymtg Bay)	0.77 +/- 0.39	9.78 +/-6.20	0.13 +/- 0.04	5.9
Riverine	1.21 +/- 0.52	-	0.13 +/- 0.06	9.3
Natural Lakes	-	-	0.24 +/- 0.01	-
Reservoirs (Flagstaff L)	1.57 +/- 1.11	-	0.24 +/-0.06	6.8

* Ratio of adult (A) and juvenile (J) blood to show age differences in mercury levels.

A total of 14 species of fish and crayfish were collected from adults bringing prey to their young. The average size was 10.5 cm (range 6.1 to 17.1 cm) in length and a weight of 13.4 g (range, 2.7 to 27.1 g). Fish size does increase with chick age and is not accounted for in Appendix 1. The mercury levels in fish ranged from 0.028 to over an order of magnitude higher in the upper Androscoggin River near Mexico (0.378 for a 9.7 cm brook trout).

Literature Cited:

Davis, W. J. 1982. Territory size in Megaceryle alcyon along a stream habitat. Auk 99:353-362.

Evers, D. C. and P. S. Reaman. 1998. A comparison of mercury exposure between artificial impoundments and natural lakes measured in Common Loons and their prey. Submitted to Central Maine Power Company, Augusta, Maine by BioDiversity Research Institute, Freeport, Maine.

Evers, D. C., J. D. Kaplan, M W. Meyer, P. S. Reaman, W. E. Braselton, A. Major, N. Burgess, and A. M. Scheuhammer. 1998. Geographic trend in mercury measured in Common Loon feathers and blood. Environ. Toxicol. Chem. 17(2):173-183.

4.2

EEL STUDY

EEL STUDY

Limited data from previous years show that eels from rivers are often among the species most highly contaminated with a number of contaminants. There are two principle fisheries for adult eels in Maine, a river fishery and a lake fishery. Most of the eels are sold outside Maine in U.S. and international markets, although some are consumed in Maine. Contaminant levels in eels from lakes are unknown. To characterize contaminant levels in each type of water, we attempted to collect eels from 3 lakes and 3 industrial rivers (Androscoggin, Kennebec, and Penobscot) with commercial fisheries. In 1998 eels were captured from 3 lakes. Concentrations were generally lower than those in eels from rivers including eels from 3 relatively pristine coastal rivers studied by Leeman (1999). We were unable to get eels from the 3 industrial rivers in either 1998 or 1999. Therefore, in 2000, we will try again to collect eels from these rivers.

Leeman, N.G.G., 1999. Mercury contamination in the silver stage of American eel, Anguilla rostrata, from three rivers in Maine. MS thesis, U of Maine, Orono, Maine.

4.3

SPMDS

SPMDS

Some SWAT funds were appropriated to augment a grant received by the Water Research Institute at the University of Maine to study semipermeable membrane devices (SPMDs). SPMDs are integrative sampling devices which combine membrane diffusion and liquid-liquid partitioning to concentrate low to moderate molecular mass hydrophobic compounds from water (Huckins et al, 1996). SPMDs have some features which give them some advantages over monitoring contaminants in fish. SPMDs can be deployed in water to accumulate single, pulsed, or continuous contaminant releases over time. SPMDs are anchored to sample at specific locations, thereby avoiding any question of origin of contaminants caused by fish movement. SPMDs do not change function under stress, unlike gills of fish. There are no biotransformations or elimination like that in fish. There are, however, a number of conditions, such as temperature, DOC, solids which can effect the efficiency of these devices. And accumulation of contaminants does not occur by the same process of uptake in fish, thereby potentially limiting their use to accumulation in a relative sense.

Made of low density polyethylene lay-flat tubing (2.5 cm wide by 91.4 cm long), containing a thin film of neutral triolein and placed inside stainless steel canisters, SPMDs are deployed in the waterbody where they accumulate contaminants until retrieved. Laboratory handling of the SPMDs after field deployment involves the removal of biofouling, which is exterior debris and periphyton, before extraction. After this initial cleanup, the devices are then spiked with a cocktail of surrogates consisting of C-13 labeled analogs of the toxic native dioxin congeners in order to monitor recovery. After surrogate addition, individual SPMDs are dialyzed and the collected dialysates are cleaned by gel permeation chromatography followed by Florisil solid phase extraction. The extracts from the three SPMDs in each deployment site canister are then combined to enhance detection and each resulting sample is concentrated to ten microliters for HR GC/MS analysis.

In order to assess the potential of SPMDs to determine if mills are discharging dioxin, WRI initiated a study in 1999 on the Penobscot River as described below.

Phase I: 1999 Field Season on the Penobscot River

Objective: To develop viable SPMD sampling techniques.

Methods: With the focus being method development, WRI tested a variety of field conditions in order to be prepared for phase II of the project which involves using SPMDs to monitor sites on the Androscoggin River in 2000.

- With the field season lasting from June to October,WRI was able to test during both low and high levels of the river. WRI deployed SPMDs at a total of nine sites and the deployments are itemized below:

Set	***Deployment Date***	***Retrieval Date***	***Sites***
1	6/18/99	7/16/99	❖ Site 1: Just upstream of Lincoln Sanitary District Discharge ❖ Site 2: In between Lincoln Sanitary District Discharge and Eastern Paper Discharge ❖ Site 3: 200 feet below Eastern Paper Discharge
2	7/21/99	8/18/99	❖ Site 3: 2 sets of SPMD were deployed so that WRI Could check for reproducibility ❖ Site 4: Near the southern tip of Mattanawcook Island ❖ Site 5: South Lincoln
3	8/20/99	9/16/99	❖ Site 3: Lincoln ❖ Site 5: South Lincoln ❖ Site 6: South Lincoln—on the opposite side of the Northern tip of Mahockanock Island as site 5 ❖ Site 7: Near the Northwestern tip of Mattanawcook Island
4	9/28/99	10/28/99	❖ Site 3: Lincoln ❖ Site 5: South Lincoln ❖ Site 8: Costigan ❖ Site 9: Grindstone

- combined to one sample for cleanup and analysis.
- Early analyses revealed that cleanup methods were inadequate. Therefore, WRI altered the methods and SPMDs were cleaned separately and the three were combined into one sample only after cleanup and just before analysis.
- Some retention time shifts still occurred after the cleanup method alterations, thus chromatographic techniques were altered. Instead of examining all homologue groups at one time WRI had separate tetra-penta and hexa-hepta runs.
- WRI is left with only small amounts of samples for further analyses. However, objectives for Phase I of the project have been met:

➢ WRI has seen that the SPMDs do scavenge for dioxins and that surrogate recoveries are within acceptable ranges.

➢ Appropriate cleanup methods have been developed and followed with some success.

- Development of the analytical capability will continue. Results are expected prior to the 2000 field season.

4.4

LANDSCAPE CONTROL OF MERCURY

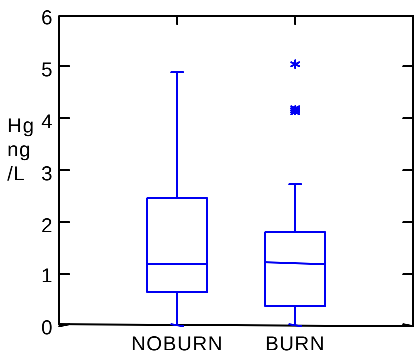
Landscape Controls on Mercury in Streams on Mount Desert Island

Objectives: To determine if the amount of mercury in stream water is controlled by landscape. In particular, to determine if there a significant difference in mercury concentrations between those areas burned in 1947 and those not burned.

Methods: Stream water was collected from actively flowing stream at 52 locations (17 in burn zone and 35 in unburned). Samples were collected under baseflow conditions in November 1999 (low baseflow), April 2000 (low baseflow), and late April/early May 2000 (high baseflow).

Results: Sample locations and results tables are attached. The mean mercury concentration was different between the burned area (1.48 ng/L) and the unburned area (1.69 ng/L), but this difference is not statistically significant. The range of values is greater for the unburned samples (Figure 1). There is a positive correlation between dissolved organic carbon (DOC) and mercury (Figure 2). There is a slightly greater mercury to DOC ratio for the burned area, but this is not a statistically significant difference. A simple interpretation of these results is that an equal amount of mercury is being added to the landscape and the unburned areas, having more organic matter can accumulate more mercury. More mercury is exported under spring baseflow than fall baseflow. In some streams the high spring baseflow had five times the mercury concentrations of low spring baseflow.

Figure 1. Mercury



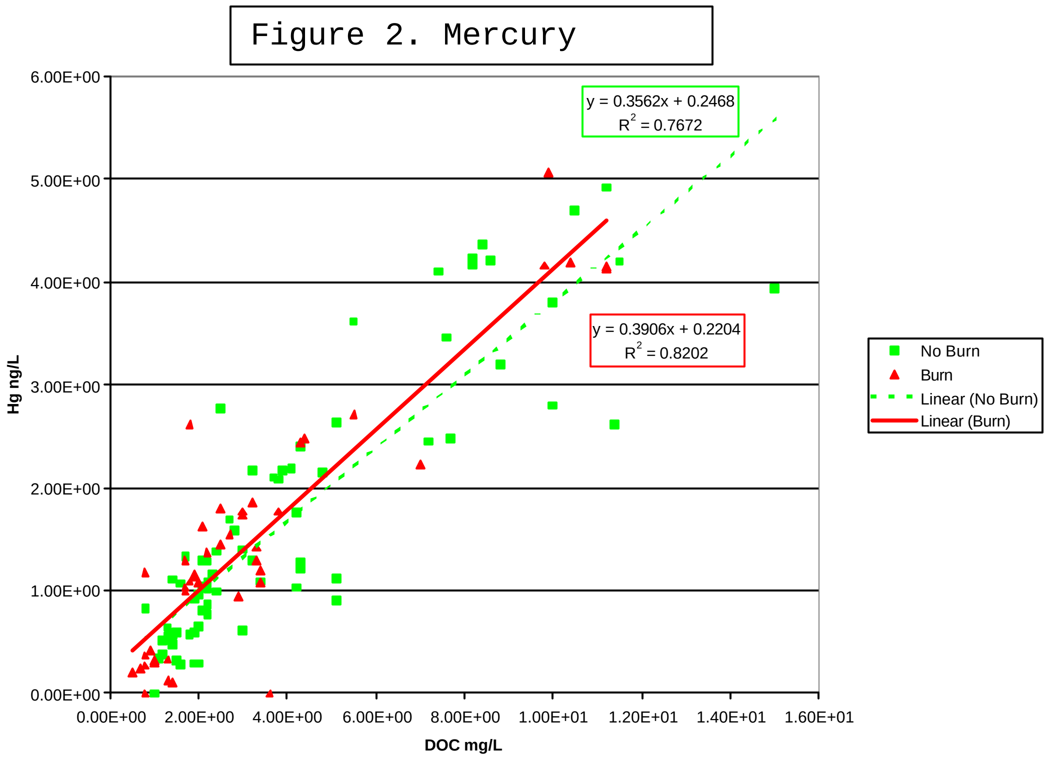


Figure 2. Mercury
6.00E+00
5.00E+00
4.00E+00
3.00E+00
2.00E+00
1.00E+00
0.00E+00
Hg ng/L
0.00E+00
2.00E+00
4.00E+00
6.00E+00
8.00E+00
1.00E+01
1.20E+01
1.40E+01
1.60E+01
DOC mg/L
y = 0.3562x + 0.2468
R2 = 0.7672
y = 0.3906x + 0.2204
R2 = 0.8202
No Burn
Burn
Linear (No Burn)
Linear (Burn)

LANDSCAPE CONTROLS ON MERCURY IN STREAMS ON MOUNT DESERT ISLAND   Water Research Institute, UMaine
Sample Locations: Mount Desert Island Mercury Sampling

Sample	**Location**
Canada Hollow	South side of access road to south end of Echo Lake
Canon Brook/Cadillac	South of peak at ~1250 feet elevation
Aunt Betty Pond Inlet	East side of carriage trail
Breakneck Brook	0.25 miles south of Park boundary
Canon Brook West	West branch of Canon ~300 feet elevation
Canon Brook/Rte. 3	West of Route 3 by Park boundary
CB-1	Confluence of Canon-Cadillac by Canon Brook trail
Chasm Brook A	Below falls to south of carriage trail
Cromwell Brook	Below Great Meadow (11/99) and by Sieur de Monts spring (4/00)
Duck Brook	By falls and carriage trail bridge below pond
Duck Cove Brook	North of Route 102 and houses
Duck Pond Inlet	Inlet on south side of Duck Pond and north of road
Duck Pond Outlet	Outlet of Duck Pond
Eagle Lake East/North	Unnamed stream (north branch) east side of Eagle Lake 100' east from loop road
Eagle Lake East/South	Unnamed stream (south branch) east side of Eagle Lake 100' and east from loop road
Eagle Lake West	Unnamed stream west side, near mid-lake, west of carriage trail
Gilmore Brook	100 feet north of carriage trail crossing
Great Brook	Lower end near Long Pond
Hadlock Brook	Above Upper Hadlock Pond and lower carriage trail crossing
HB-1	Near USGS stream gauge
HBB	Small tributary in upper Hadlock drainage to east
HBC	Small tributary in upper Hadlock drainage near foot trail
HBE	Small tributary in upper Hadlock drainage to west of Maple Spring
Hodgdon Brook	Lower end near Hodgdon Pond
Hunters Brook South	To east of Park Loop Road crossing and north of Route 3
Little Harbor Brook	0.25 miles north of Route 3 above tidal zone
Little Hunters Brook	500 feet north of Park Loop Road
Lower Old Mill	75' south of intersection of Hull's Cove and Salibury Cove Roads
Marshall Brook	End of seasonal road by Park Boundary and Tremont town line
North Deer Brook	0.25 miles north of Jordan Pond at ~300 feet elevation
Norwood Cove	0.25 miles east of Route 102 at point where brook turns east, near houses

Oak Hill Stream	1 mile west of Somesville, north of Somes Pond and road by dry hydrant
Parkman Brook	North of carriage trail crossing
Sample Locations: Mount Desert Island Mercury Sampling-Continued	
Pemetic Brook	Drainage off of pemetic Mountain to west of carriage trail crossing
Richardson Brook	150 feet east of Route 3 by small falls
Sargent Brook	100 feet east of Route 3 upstream of houses
South Kebo Brook	Main stem of Kebo Stream 300 feet south of Park Loop Road
Squid Cove Brook	100 feet east of Pretty Marsh Road and east of Squid Cove
Stanley Brook	East side of Park Road, 1 mile north of Route 3
Steward Brook	By end of stream and Seal Cove Pond
Stony Brook	300 feet east of road across from pond
The Reservoir	Upstream of reservoir, south side of Bernard Mountain
Upper Little Harbor	Carriage trail crossing ~200 feet elevation
Upper Old Mill	South of east-west dirt road, ~ 100 feet elevation
West Kebo Brook	West branch of Kebo Stream 0.5 miles south of Park Loop Road ~ 200 feet elev.
Whalesback	300 feet east of Route 102, ~1 mile north of intersection with Route 3

Summary of Mercury in Stream Water Results.

	Nov-99	Apr-00	Apr-00
Mercury in Streams Mount Desert Island	**Hg (ng/L)**	**Hg (ng/L)**	**Hg (ng/L)**
Canada Hollow	1.21	1.15	NS
Canon Brook/Cadillac	1.29	NS	2.72
Aunt Betty Pond Inlet	2.23	NS	2.48
Aunt Betty Pond Inlet-Dup.	NS	NS	2.44
Breakneck Brook	ND	0.96	1.59
Canon Brook West	0.29	NS	1.29
Canon Brook West	0.32	NS	NS
Canon Brook/Rte. 3	1.85	1.80	1.54
CB-1	0.11	0.27*	0.94
CB-1-Dup.	NS	0.33*	NS
Chasm Brook A	0.12	0.38*	0.64
Cromwell Brook	4.15	NS	1.62
Cromwell Brook-Dup.	4.13	NS	NS
Duck Brook	1.42	1.73	1.08
Duck Brook-Dup.	1.29	1.68	1.16
Duck Cove	3.80	4.10	NS
Duck Pond Brook	1.11	1.76	NS
Duck Pond Brook-Dup.	0.90	1.76	NS
Duck Pond Inlet	0.61	1.76	NS
Eagle Lake East/North	0.57	0.59	1.09
Eagle Lake East/South	1.29	0.91	1.69
Eagle Lake West	1.45	1.77	2.61
Gilmore Brook	0.32*	NS	1.38
Gilmore Brook-Dup.	0.31*	NS	NS
Great Brook	0.29*	0.52	NS
Great Brook-Dup.	NS	0.44*	NS
Hadlock Brook	1.11	0.47*	1.40
HB-1	0.28*	0.48*	1.33
HBB	2.80	NS	3.20
HBC	0.65	NS	1.51
HBE	2.18	NS	2.17
Hogdon Brook	2.62	4.21	NS
Hunters Brook South	1.07	0.56	1.04
Little Harbor Brook	0.81	NS	1.02
Little Harbor Brook	NS	NS	0.99
Little Hunters Brook	NS	2.63	4.17

	Nov-99	Apr-00	Apr-00
Mercury in Streams Mount Desert Island	**Hg (ng/L)**	**Hg (ng/L)**	**Hg (ng/L)**
Little Hunters Brook-Dup.	NS	2.72	4.24
Lower Old Mill	3.62	NS	2.08
Marshall Brook	NS	2.45	NS
North Deer Brook	1.14	1.09	1.03
North Deer Brook-Dup.	NS	0.99	1.03
Norwood Cove	2.48	2.05	NS
Norwood Cove-Dup.	2.47	NS	NS
Oak Hill Stream	NS	4.92	4.20
Parkman Brook	ND	NS	0.57
Pemetic Brook	0.87	0.59	2.77
Richardson	NS	2.15	4.37
Sargent Brook	0.29*	0.60	2.40
South Kebo Brook	ND	0.2*	0.37*
South Kebo Brook-Dup.	ND	NS	NS
Squid Cove Brook	3.96	NS	NS
Stanley Brook	1.09	1.28	2.10
Steward Brook	NS	0.76	NS
Stony Brook	3.94	4.69	3.46
Stony Brook-Dup.	NS	4.63	NS
The Reservoir	0.4*	NS	NS
Upper Little Harbor	NS	0.34*	0.82
Upper Old Mill	1.08	1.37	1.77
Upper Old Mill-Dup.	1.20	NS	NS
West Kebo Brook	1.17	0.25*	0.42*
Whalesback	NS	5.06	4.16
Whalesback-Dup.	NS	NS	4.19

Notes: * = estimated; ND = none detected @ 0.02 ng/L; NS = not sampled.